Claims

1. Method of producing a layer of a sol-gel on a substrate comprising the steps of

   (a) providing an acidified sol suspension;

   (b) at least partially neutralising the acidified sol suspension to form a neutralised sol suspension;

   (c) contacting an electrically conductive surface with the neutralised sol suspension; and

   (d) applying an electrical potential to the electrically conductive surface to cause a layer of sol-gel to form on the surface of the electrically conductive surface.

2. A method according to claim 2, additionally comprising the step of adding one or more biological materials to the neutralised sol suspension, prior to applying the electrical potential to the electrically conductive surface (step C).

3. A method according to claim 2, wherein the biological material selected from an enzyme, antibody, fragment of an antibody, nucleic acid, polysaccharide, oligosaccharide, biomimetic polymers, virus, microorganism or a whole cell.

4. A method according to any preceding claims, wherein the acidified sol suspension has a pH of less than pH 4.

5. A method according to any preceding claim wherein the acidified sol suspension is neutralised to between pH 5 and pH 7.5.

6. A method according to any preceding claim wherein the acidified sol suspension is neutralised by the addition of a buffer.

7. A method according to any preceding claim wherein the sol comprises a sol of alkoxysilane, alumina, colloidal metal hydroxide, ceramic oxide or zirconia.

8. A method according to claim 7, wherein the sol has the general formula:

or $(R_9O)_3$-Si-CH_2-CH_2-Si-$(OR_9)_3$

where:

R_1 = straight chain, branched chain, cyclic, non-cyclic, saturated or non-saturated, substituted or non-substituted alkyl; substituted or non-substituted aryl; -NR_5; and -COR_6; preferably containing 1, 2, 3, 4, 5 or 6 carbons;

R_2, R_3 and R_4 are independently selected from; straight chain and branched chain, cyclic or non-cyclic, saturated or non-saturated alkyl; -COR_6; -O-alkyl; and -O-COR_6; -R_7R_8; $R_7N(R_6)_2$ and $R_7NHR_6R_8$; preferably containing 1, 2, 3, 4, 5, or 6 carbon atoms;

R_5 = branched or non-branched cyclic or non-cyclic, saturated or non-saturated alkyl; or , preferably containing 1, 2, 3, 4, 5, or 6 carbon atoms;

R_6 = C_1 to C_3 alkyl;

R_7 = C_1 to C_6 alkyl, especially C_1, C_2 or C_3 alkyl;

R_8 = Epoxy, -NH_2 or -SH; especially -CH_2-CH_2, or -$CH_2CH_2CH_2$ 

R_9 = Straight or branched C_1 to C_6 alkyl.

9. A method according to claim 8, wherein the sol is methyltrimethoxysilane (MeTMOS) or tetramethylsilicate (TMOS).

10. A method according to any preceding claim wherein the electrical potential applied to the electrically conductive surface is -900 to -1500 mV.

11. A method according to any preceding claim, wherein the electrical potential is applied for 20 to 120 seconds.

12. A method according to any preceding claim wherein the acidified sol suspension does not contain an alcohol and/or an electroreducer.

13. A method according to any preceding claim wherein an alcohol and/or an electroreducer is incorporated into the neutralised sol suspension.

14. A method according to any preceding claim comprising adding a silane coupling agent.

15. A method according to claim 14, comprising incorporating functionalised or non-functionalsied APTEOS the neutralised sol suspension.

16. A method according to claim 15, wherein the APTEOS is functionalised with a ferrocene, gluconamide or a lactiobionic group.

17. A method according to any preceding claim additionally comprising the addition of a mercaptan-containing silane and/or a bisfunctional silane.

18. A method according to any preceding claim, wherein the neutralised sol suspension additionally comprises one or more stabilisers.

19. A method according to claim 18 wherein the stabiliser is selected from a polyhydroxyalcohol, such as glycerol, polyethylene glycol or polyvinyl alcohol; polysaccharides, such as dextran or chitosan; polyalkylene imine; or sugars, such as mannitol, gluconate, lactitol or sucrose.

20. A method according to any one of claims 3 to 19, wherein the enzymes are selected from xanthine oxidase, glucose oxidase, lactate oxidase, cholesterol oxidase, galactose oxidase, glutamate oxidase, horse radish peroxidase, polyphenol oxidase, D-fructose dehydrogenase, L-glutamate dehydrogenase, alcohol dehydrogenase (such as methanol dehydrogenase), urease, uricase, lactate dehydrogenase, glutamic pyruvic transaminase, creatinase, sarcosine oxidase, glutaminase, nucleoside phosphorylase, ascorbate oxidase, cytochrome C oxidase, adenosine deaminase, D- or L-amino acid oxidase, tyrosinase and/or cholinedehydrogenase.

21. A method according to any one of claims 3 to 20, wherein two or more enzymes are used.

22. A method according to claim 21 wherein each enzyme is applied as a separate layer.

23. A method of producing a biological assay device, such as a biosensor or a microarray, comprising the use of a method, as defined in any preceding claim to produce a layer of sol-gel containing a biological material onto a substrate.

24. A method according to claim 23, wherein the electrically conductive surface is an electrode.

25. A method according to claim 24, wherein the biosensor or microarray comprises two electrodes, each electrode having a layer of sol-gel having a different biorecognition element within it, formed by applying an electrical potential to a first electrode when in contact with a first neutralised sol suspension containing a first biorecognition element; and
selectively applying an electrical potential to a second electrode, when the second electrode is in contact with a second neutralised sol suspension containing a second biorecognition element.

26. A biological assay device obtainable by a method according to any preceding claim.

27. A biological assay device comprising:

(i) an electrically conductive substrate;
(ii) a sol-gel comprising one or more biological materials.

28. A biological assay device according to claim 26, wherein the sol-gel is obtained from a mixture comprising a mercaptan-containing silane and/or a bisfunctional silane.

29. In combination, a biological assay device according to any one of claims 26 to 28 with a potentiometer.

30. Use of a biological assay device according to any of claims 26 to 28 or the combination according to claim 29, to detect one or more analytes.